

## COMBINING ABILITY AND HETEROSIS FOR YIELD AND YIELD ATTRIBUTING TRAITS IN BITTER GOURD

### ABSTRACT

A study was conducted during *Rabi* 2022 and *Kharif* 2023 at the Department of Horticulture, University of Agricultural Sciences, Bangalore to develop 49 F<sub>1</sub> hybrids through the utilization of line × tester mating design. The parents and developed hybrids along with standard check (Pusa Hybrid 6) were evaluated in **Randomized Complete Block Design** and Alpha lattice design, respectively, for yield and yield attributing traits. The combining ability analysis revealed that among 14 parents, Pusa Rasdar, Pusa Do Mausami, Pusa Vishesh, Hirkani and Pant Karela 4 were identified as best general combiners for most of the studied yield and yield attributing traits. The estimates of heterosis revealed that the hybrids, Konkan Karali × Pant Karela 4 (45.45 %), Konkan Tara × Pusa Do Mausami (23.48 %), Pusa Rasdar × Phule Green Gold (126.87 %) and Hirkani × Pusa Do Mausami (46.20 %) were top performing hybrids over standard check for fruit length, diameter, average weight and number of fruits per vine, respectively. Similarly, Pusa Rasdar × Pant Karela 4 (127.06 %), Priya × Pusa Do Mausami (101.05 %), Punjab 14 × Pusa Do Mausami (100.53 %) and Pusa Rasdar × Pant Karela 3 (97.61 %) were top performing hybrids over standard check for yield per vine. These hybrids also recorded highest significant *sca* effects hence, considered as good specific combiners.

**Key words:** Combining ability; *gca*; *sca*; Heterosis; Bitter gourd; yield

### Introduction

Bitter gourd (*Momordica charantia* L.) known by various names such as Balsam pear, bitter cucumber or bitter melon is a member of the cucurbitaceous vegetable family Cucurbitaceae. Bitter gourd is diploid having chromosome number  $2n=2x=22$  and has its origin in the Indo-Burma region. Bitter gourd is cultivated primarily for its bitter and tender fruits, which are renowned for their rich nutritional compositions, vitamin A and C (Gopalan et al., 1993).

The characteristic bitter taste of bitter melon is attributed to specific compounds, including the cucurbitacin-like alkaloid momordicine and triterpene glycosides such as momordicoside K and L (Jeffrey, 1980 and Okabe *et al.*, 1982). Beyond its culinary appeal, bitter melon has garnered attention for its potential health benefits, particularly in managing diabetes. Studies have revealed the presence of a hypoglycemic compound named 'charantin' in bitter melon, suggesting its efficacy in regulating blood sugar levels (Yeh *et al.*, 2003).

The traditional approaches to parent selection in breeding programmes, based solely on individual performance, often fall short of achieving desirable outcomes (Allard, 1960). Hence, it is imperative to consider the genetic architecture and combining ability of potential parent genotypes in addition to their inherent traits. Combining ability is the measure of a genotypes relative capacity to pass on its desirable traits to its offspring. The enhancement of yield and correlated traits in bitter gourd has been extensively recorded, with improvement achieved through heterosis breeding techniques (Sekar *et al.*, 2014). Hybrids offer opportunities for improvement in productivity, quality, earliness, uniformity, wider adaptability and the rapid development of dominant genes for resistance to diseases and pests. The predominance of dominant gene action coupled with low heritability observed for most of yield traits indicating the importance of heterosis breeding for improvement of yield and yield attributing traits in bitter gourd (Rani *et al.*, 2014). Heterosis and combining ability studies are thus crucial for providing insights into crop improvement strategies (Hallauer and Miranda, 1981). Therefore, this research aims to explore the genetic mechanisms underlying yield and yield attributing traits in bitter gourd and develop superior varieties through line  $\times$  tester mating designs contributing to sustainable agriculture and human health.

## MATERIALS AND METHODS

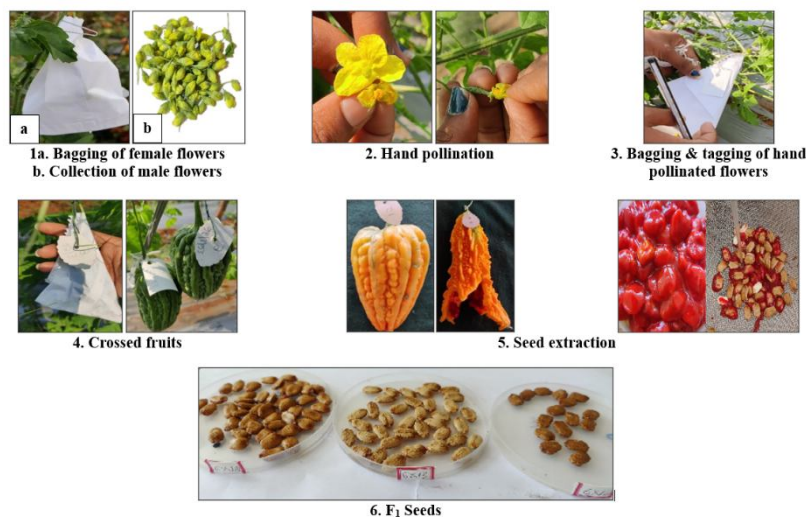
The study on combining ability and heterosis in bitter gourd was conducted during *Rabi* 2022 and *Kharif* 2023 at the Department of Horticulture, University of Agricultural Sciences, Bangalore. Twelve genotypes were crossed in line  $\times$  tester mating design (Kempthorne, 1957) (Fig 1) during *Rabi* 2022 to develop 49 F<sub>1</sub> hybrids. The important features of the parents along with their source of collection used in this study are presented in Table 1. All the parents with their respective hybrids and the check variety Pusa Hybrid 6, were planted during *Kharif* 2023

using a Randomized Complete Block Design (RCBD) for the parents and an Alpha Lattice design for the hybrids and check variety, with each treatment replicated three times, to assess the combining ability effects, magnitude and direction of heterosis among them. To prevent any interference between parents and their crosses, they were assessed separately in two distinct experimental designs. The observations were recorded for 17 parameters such as growth, flowering and yield traits and the data was collected from 5 randomly selected plants in each replication. The statistical analysis was done using Microsoft excel for RCBD, R studio for alpha lattice and Indostat version 9.1 for the combining ability analysis and heterosis.

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**Table 1. Details of parents taken for hybridization along with their salient features and source of collection**

<b>Code</b>	<b>Genotypes</b>	<b>Salient features</b>	<b>Source of collection</b>
<b>Lines</b>			
L <sub>1</sub>	Punjab 14	Plants are bushy and bear light green fruits with average weight of 35 g. Yield 14 t ha <sup>-1</sup> .	NSC, New Delhi
L <sub>2</sub>	Hirkani	Fruits dark green, 15-20 cm long, spindle shaped with warts and prickles, yield t ha <sup>-1</sup> in 160 days.	MPKV, Rahuri
L <sub>3</sub>	Pusa Rasdar	Fruits juicy, smooth, non-prickled with tender skin, fleshy and dark green colour. Average fruit weight is 110 g with an average yield of 0.5 t/ 100 sqm in insect proof net-house.	IARI, New Delhi
L <sub>4</sub>	Pusa Purvi	First small fruited variety, dark green colour fruits, small size (4-5 cm long and 3-4 diameter) and crispy flesh with high dry matter. Average yield is 8.78 t ha <sup>-1</sup> .	IARI, New Delhi
L <sub>5</sub>	Priya	Extra long green spiny fruits with white tinge at stylar end, average fruit length 39 cm. Average fruit weight 235 g with a productivity of 24.5 t ha <sup>-1</sup> .	KAU, Thrissur
L <sub>6</sub>	Konkan Tara	Fruits green, prickly, medium long (15-16 cm) and spindle shaped. Yield 24 t ha <sup>-1</sup> .	KKV, Dapoli
L <sub>7</sub>	Konkan Karali	Long attractive sharp prickled, dark shiny green colour fruits suitable for high rainfall areas with a yield of 16-18 t ha <sup>-1</sup> .	KKV, Dapoli
<b>Testers</b>			
T <sub>1</sub>	Pant Karela 3	Cylindrical dark green fruits with a length of 24 cm, suitable for plain and hilly areas with a yield of 15-16 t ha <sup>-1</sup> .	GBPUAT, Pantnagar
T <sub>2</sub>	Pant Karela 4	Dark green fruits with a length of 30-35 cm. Yield 12.5-15 t ha <sup>-1</sup> .	GBPUAT, Pantnagar
T <sub>3</sub>	CO 1	Dark green fruits with medium length (20-25 cm) and weight (100-120 g). Yield 14 t ha <sup>-1</sup> .	TNAU, Coimbatore
T <sub>4</sub>	Preethi	Medium sized white fruits with spines, average fruit length 30 cm, average fruit girth 24 cm, average fruit weight 0.31 kg with a productivity 15 t ha <sup>-1</sup> .	KAU, Thrissur
T <sub>5</sub>	Phule Green Gold	Fruits dark green, 25-30 cm long, prickled, tolerant to downy mildew, yield 23 t ha <sup>-1</sup> in 160-180 days.	MPKV, Rahuri
T <sub>6</sub>	Pusa Do Mausami	Fruits are dark green, club like shape with 7-8 continuous ribs. Fruit weight is 100-120 g with a yield 12-15 t ha <sup>-1</sup> .	IARI, New Delhi
T <sub>7</sub>	Pusa Vishesh	Selection from a local collection and suitable for growing during summer. Fruits are glossy green in colour, medium long and thick.	IARI, New Delhi



**Fig 1: Hybridization technique followed during the experiment**

## RESULTS AND DISCUSSION

*Analysis of variance and gene action:* The analysis of variance performed for enhancing the quality of crop is contingent upon the availability of genetic diversity among the parents and their offspring for the desired characteristics. The ANOVA indicated that mean sum of squares of all the treatments were highly significant at  $p=0.001$ . Similarly, variance owing to lines, testers and crosses was substantial ( $P<0.05$ ) for majority of the traits. Results of the investigation revealed that all the characters studied exhibited higher sca variance indicating the preponderance of non-additive genes in control of the characters studied. The ratio of GCA/SCA variance was not found near to unity for any of the trait under study which showed the involvement of additive and non-additive gene action in their expression. The results are in harmony with earlier findings of Acharya *et al.* (2019) in bitter gourd, Ene *et al.* (2019) in cucumber and Napolitano *et al.* (2020) in melons.

*Combining ability and heterosis:* The analysis of general combining ability effects among parental lines in bitter gourd reveals significant variations in estimates of GCA both among different parents for specific traits and within a parent across various traits (Table 2). For instance, among 17 traits, genotype L3 exhibited the maximum *gca* effects for 12 traits, followed by T7 for 11 traits, T6 and L5 for 9 traits each. The parent L2 displayed positive *gca* effects

specifically for the number of fruits per vine and fruit yield per vine. Notably, L4 exhibited significant *gca* effects for the number of fruits per vine, with the smallest fruit size having the maximum negative *gca* effects on average fruit weight. These findings underscore the importance of specific parental lines in influencing reproductive development and yield-related characteristics in bitter melon, providing valuable insights for breeding programs.

The top three best crosses, identified for their significant and desirable specific combining ability effects and heterosis over standard check, for all the yield and yield attributing traits are presented in **Table 3**. The results of the study unveil significant insights into the *sca* effects and heterosis in bitter melon hybrids, particularly focusing on essential fruit-related traits. Among the 49 hybrid combinations assessed, notable findings emerged across various parameters. For instance, the hybrid L2 × T6 displayed the minimum number of days for germination and exhibited the highest negative standard heterosis. Conversely, hybrids like L4 × T7 showcased maximum positive *sca* effects for germination percentage while L4 × T3 demonstrated the highest heterosis over the standard check. In terms of fruit morphology, significant *sca* effects and heterosis were observed for traits such as fruit length, diameter and average fruit weight. Hybrids such as L7 × T2 exhibited the highest positive *sca* effects for fruit length, while L7 × T6 displayed the highest negative *sca* effects. Moreover, maximum standard heterosis was observed in the cross L7 × T2, indicating its potential for enhancing fruit length significantly. Similar trends were observed for fruit diameter with hybrids showing contrasting *sca* effects and heterosis values. Notably, hybrids like L6 × T4 displayed the highest positive *sca* effects for average fruit weight whereas, L3 × T4 showcased the highest negative *sca* effects. Furthermore, the study revealed significant findings concerning yield-related traits, particularly yield per vine. Hybrids such as L5 × T6 exhibited substantial *sca* effects for yield per vine, followed by L6 × T4 and L1 × T6. These hybrids demonstrated considerable heterosis over the standard check, highlighting their potential for yield enhancement. The total yield per vine primarily relies on the number of fruits per vine and the average fruit weight. The quantity of fruits per vine is influenced by factors such as the size of the fruit, including its length and girth. Similar findings are reported by Hossain *et al.* (2016), Talekar *et al.* (2013), Singh *et al.* (2013), Singh *et al.* (2007) and Panda (2008) in bitter melon. Overall, these findings shed light on the genetic

mechanisms underlying fruit-related traits in bitter gourd hybrids and provide promising avenues for breeding programs aimed at improving yield and yield attributing traits.

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**Table 2. General combining ability effects for yield and yield attributing parameters in bitter melon**

Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
<b>L1</b>	-0.574 ***	4.939 ***	0.174 *	-0.891	-0.001	0.721 ***	1.476 ***	0.490 ***	-0.925 ***	0.742 ***	-3.172 ***	-3.915 ***	0.095	-0.057	6.974 **	-1.844 ***	0.006
<b>L2</b>	-0.815 ***	-1.587 ***	0.009	-1.129	0.261 *	0.912 ***	-0.143	1.395 ***	1.884 ***	-0.913 ***	0.533 ***	1.446 ***	-0.072	0.016	1.930	2.575 ***	0.257 ***
<b>L3</b>	0.512 ***	1.129 **	0.282 ***	20.680 ***	0.608 ***	-3.422 ***	-4.095 ***	-1.415 ***	-2.068 ***	-3.870 ***	-3.978 ***	-0.109	1.337 ***	0.486 ***	30.522 ***	0.429	0.674 ***
<b>L4</b>	-0.126	-4.060 ***	-0.449 ***	-19.463 ***	-0.725 ***	0.245	2.524 ***	0.156	2.837 ***	1.618 ***	2.699 ***	1.080 ***	-4.358 ***	-0.574 ***	-31.282 ***	4.387 ***	-0.451 ***
<b>L5</b>	0.679 ***	2.129 ***	0.336 ***	20.347 ***	-0.130	0.673 ***	-1.810 ***	0.347 **	-2.306 ***	-0.783 ***	0.960 ***	1.744 ***	0.799 *	0.058	1.246	-1.989 ***	-0.048
<b>L6</b>	-0.312 *	0.700	-0.417 ***	-18.415 ***	-0.225	-1.136 ***	0.714 ***	-0.891 ***	-0.163	1.224 ***	1.179 ***	-0.044	0.828 *	0.580 ***	-0.940	-2.564 ***	-0.204 ***
<b>L7</b>	0.636 ***	-3.250 ***	0.066	-1.129	0.213	2.007 ***	1.333 ***	-0.082	0.741 ***	1.982 ***	1.779 ***	-0.202	1.371 ***	-0.509 ***	-8.450 **	-0.996 **	-0.234 ***
<b>T1</b>	-0.293 *	10.178 ***	-0.271 ***	-9.510 ***	0.513 ***	1.054 ***	0.000	-1.177 ***	-1.259 ***	0.105	-1.232 ***	-1.337 ***	1.180 **	-0.163	-3.879 ***	-3.621 ***	-0.265 ***
<b>T2</b>	1.251 ***	7.178 ***	0.059	6.014 ***	0.118	-0.279	0.381 *	0.061	0.694 ***	1.679 ***	1.198 ***	-0.482 ***	3.466 ***	0.191 *	8.065 ***	-1.253 ***	0.123 **
<b>T3</b>	0.780 ***	5.748 ***	-0.163 *	-10.320 ***	-0.478 ***	0.007	-1.143 ***	-0.082	-2.401 ***	-2.250 ***	-0.992 ***	1.259 ***	-2.591 ***	-0.085	-7.666 ***	0.536	-0.125 **
<b>T4</b>	-0.752 ***	-6.253 ***	-0.461 ***	-23.224 ***	-0.178	-0.517 ***	1.619 ***	-0.415 **	0.884 ***	0.665 ***	0.026	-0.639 ***	-2.810 ***	-0.049	-3.581 ***	-0.771 *	-0.110 **
<b>T5</b>	-0.278 *	-7.774 ***	-0.104	-4.129 ***	0.427 ***	1.293 ***	2.190 ***	1.395 ***	1.408 ***	1.861 ***	0.610 ***	-1.250 ***	0.495	-0.026	6.759 ***	-1.649 ***	-0.042
<b>T6</b>	-0.653 ***	-6.347 ***	0.311 ***	17.776 ***	-0.082	-0.136	-1.286 ***	0.823 ***	0.170	0.047	1.196 ***	1.149 ***	2.552 ***	0.075	-3.052 ***	5.386 ***	0.329 ***
<b>T7</b>	-0.055	-2.730 ***	0.628 ***	23.395 ***	-0.320 *	-1.422 ***	-1.762 ***	-0.605 ***	0.503 **	-2.108 ***	-0.805 ***	1.302 ***	-2.291 ***	0.056	3.355 ***	1.371 ***	0.090 *
<b>S.Em ±</b>	0.12	0.41	0.07	1.03	0.13	0.14	0.16	0.12	0.19	0.13	0.12	0.10	0.36	0.09	0.71	0.36	0.04
<b>C.D @ 5%</b>	0.25	0.81	0.15	2.03	0.25	0.28	0.33	0.25	0.38	0.26	0.24	0.20	0.71	0.18	1.42	0.72	0.08
<b>C.D @ 1%</b>	0.33	1.07	0.19	2.69	0.33	0.37	0.43	0.33	0.50	0.34	0.32	0.27	0.94	0.24	1.88	0.95	0.10

\*Significance at P = 0.05, \*\* Significance at P = 0.01, \*\*\* Significance at P = 0.001

1. Days taken for germination (No.) 2. Germination percentage 3. Vine length 90 DAS (m) 4. Number of leaves per vine (90 DAS) 5. Internodal length (cm) 6. Days to first male flower appearance 7. Days to first female flower appearance 8. Node of first male flower appearance 9. Node of first female flower appearance 10. Days to first harvest of fruits 11. Days to final harvest of fruits 12. Fruiting period (days) 13. Fruit length (cm) 14. Fruit diameter (cm) 15. Average fruit weight (g) 16. Number of fruits per vine 17. Fruit yield per vine (kg)

**Table 3.** List of top three Parents with *gca* effects, F<sub>1</sub> hybrids with their *sca* effects and standard heterosis for yield and yield attributing traits

Traits	Parents	<i>gca</i> effects	F <sub>1</sub> hybrids	<i>sca</i> effects	F <sub>1</sub> hybrids	Standard Check (%)
Number of days taken for germination	L2	-0.815	L5 × T4	-0.934	L2 × T4	-34.47
	T4	-0.752	L7 × T3	-0.923	L2 × T5	-34.47
	T6	-0.653	L3 × T1	-0.726	L2 × T7	-34.47
Germination percentage	T1	10.178	L4 × T7	33.826	L4 × T3	21.58
	T2	7.178	L1 × T6	27.445	L4 × T7	21.58
	T3	5.748	L4 × T3	25.349	L5 × T1	21.58
Vine length at 90 DAS (m)	T7	0.628	L3 × T5	1.131	L3 × T7	63.97
	L5	0.336	L6 × T6	1.089	L5 × T6	58.36
	T6	0.311	L7 × T3	0.840	L3 × T5	57.11
Number of leaves at 90 DAS	T7	23.395	L3 × T5	59.891	L3 × T7	26.72
	L3	20.680	L7 × T3	52.224	L3 × T5	26.62
	L5	20.347	L7 × T2	51.224	L5 × T6	25.13
Internodal length (cm)	L4	-0.725	L5 × T5	-2.284	L4 × T3	-33.33
	T3	-0.478	L7 × T1	-1.980	L5 × T5	-28.07
	T7	-0.320	L1 × T7	-1.499	L1 × T7	-26.32
Days to first male flower	L3	-3.422	L2 × T2	-4.483	L3 × T1	-14.53
	T7	-1.422	L6 × T6	-3.912	L3 × T7	-14.53
	L6	-1.136	L7 × T7	-3.769	L6 × T6	-14.53
Days to first female flower	L3	-4.095	L3 × T5	-7.905	L3 × T5	-26.98
	L5	-1.810	L7 × T3	-7.000	L5 × T6	-25.40
	L6	-1.762	L2 × T2	-6.381	L3 × T1	-20.63
Node of first male flower	T1	-1.177	L5 × T6	-2.537	L7 × T1	-22.22
	L3	-1.415	L1 × T3	-2.442	L3 × T3	-16.67
	L6	-0.891	L6 × T5	-2.204		
Node of first female flower	T3	-2.401	L4 × T6	-5.075	L3 × T2	-55.56
	L5	-2.306	L3 × T2	-4.027	L7 × T3	-55.56
	L3	-2.068	L4 × T1	-3.980	L3 × T1	-50.00
Days to first harvest of fruits	L3	-3.870	L7 × T3	-6.771	L3 × T1	-21.42
	T3	-2.250	L2 × T2	-5.809	L7 × T3	-18.48
	T7	-2.108	L4 × T4	-5.306	L1 × T7	-17.02
Days to last harvest of fruits	L4	2.699	L1 × T3	6.794	L5 × T2	13.44
	T2	1.198	L3 × T6	6.201	L7 × T4	12.52
	T6	1.196	L5 × T2	5.261	L4 × T3	11.60
Fruiting period (days)	L5	1.744	L4 × T3	8.919	L4 × T3	46.95
	L2	1.446	L7 × T7	2.781	L2 × T7	34.39
	T7	1.302	L7 × T1	2.657	L2 × T6	33.28
Fruit length (cm)	T2	3.466	L7 × T2	5.591	L7 × T2	45.45
	T6	2.552	L5 × T1	4.448	L6 × T6	24.18
	L7	1.371	L2 × T4	3.344	L5 × T1	23.64
Fruit diameter (cm)	L6	0.580	L7 × T7	1.408	L6 × T6	18.95

	L3	0.486	L4 × T2	0.949	L3 × T7	23.48
	T2	0.191	L5 × T5	0.904	L7 × T7	21.80
Average fruit weight (gm)	L3	30.522	L6 × T4	42.528	L3 × T5	126.87
	T2	8.065	L5 × T6	36.814	L3 × T7	99.02
	L1	6.974	L3 × T5	32.527	L3 × T2	88.60
Number of fruits vine <sup>-1</sup>	L2	2.575	L2 × T5	6.430	L2 × T6	46.20
	L4	4.387	L7 × T3	6.316	L4 × T5	43.28
	T6	5.386	L3 × T1	6.251	L2 × T5	35.25
Yield vine <sup>-1</sup> (kg)	L3	0.674	L5 × T6	0.861	L3 × T2	127.06
	T6	0.329	L6 × T4	0.804	L5 × T6	101.59
	L2	0.257	L1 × T6	0.795	L1 × T6	100.53

## CONCLUSION

Among the parents, L3, T6, T7 and L2 exhibited significant *gca* effects for yield and yield attributing traits. The hybrids that exhibited substantial heterosis involved one of these parents, demonstrating high heterosis for yield and yield contributing characters. Therefore, selecting these genotypes as parents for developing hybrids could be an effective strategy for exploiting heterosis in fruit yield per vine. In such a scenario, heterosis breeding would be a rewarding approach for crop improvement in bitter melon. Based on the overall performance, significant *sca* effects and desirable heterosis, the top high-yielding crosses identified are L3 × T2, L5 × T6, L1 × T6, L3 × T1 and L3 × T7. These crosses exhibited potential for commercial exploitation of hybrid vigour in terms of fruit yield per plant. This comprehensive evaluation shall provide valuable insights into the stability and adaptability of these high-yielding hybrid combinations, ultimately contributing to the advancement of bitter melon cultivation practices and the improvement of crop productivity in agricultural environment.

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